GILBERT TERCENTENARY CELEBRATION

DECEMBER 10TH, 1903

GILBERT OF COLCHESTER

FATHER OF ELECTRICAL SCIENCE

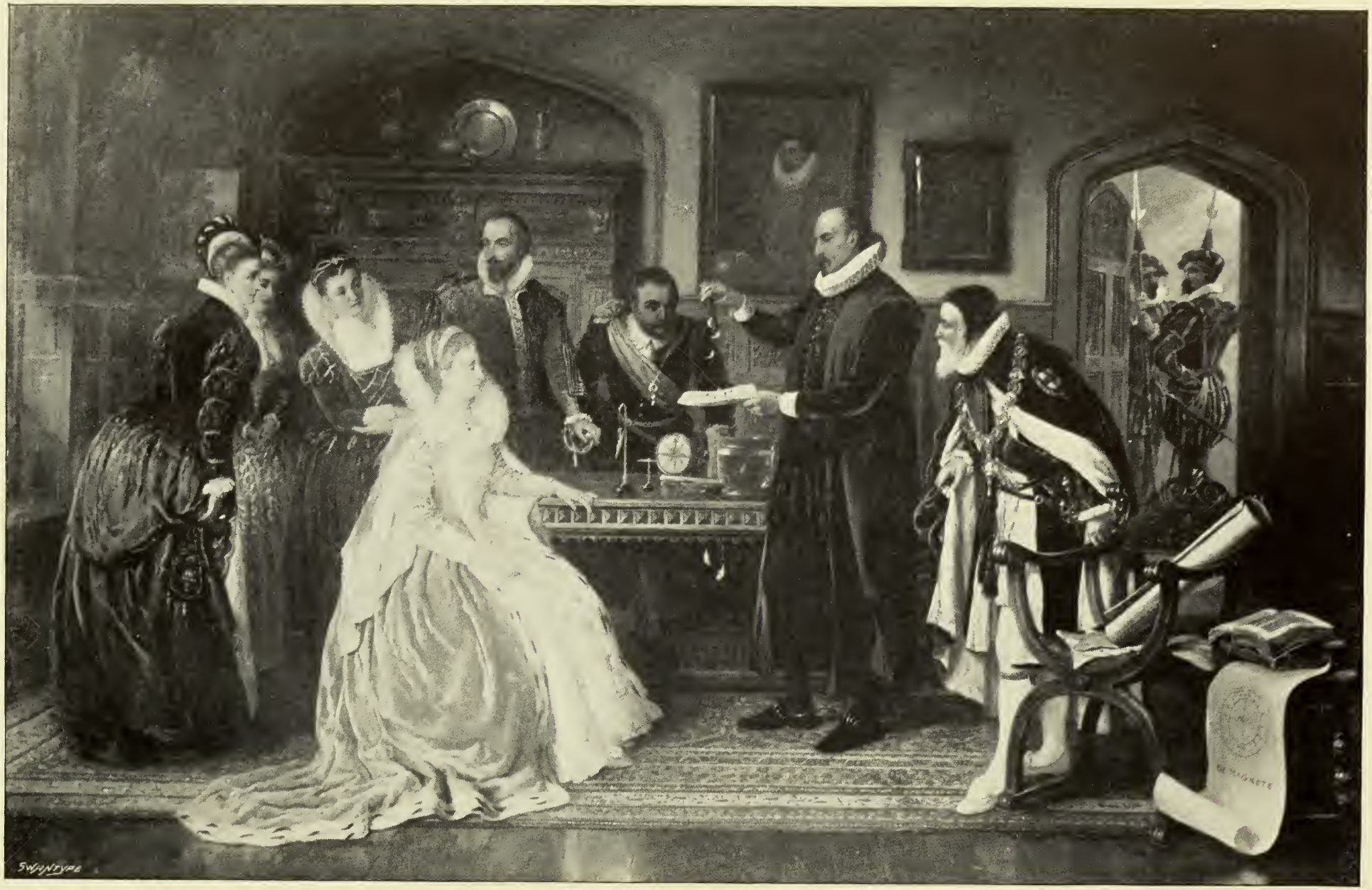
Born May 24th, 1544

Died Dec. 10th, 1603

RÖNTGEN

J.C. Bernal

11.12.41.



A. Ackland Hunt, pinxit.

GILBERT SHEWING HIS EXPERIMENTS ON ELECTRICITY TO QUEEN ELIZABETH AND HER COURT.

Gilbert Tercentenary Commemoration, December 10, 1903

Gilbert of Colchester

FATHER OF ELECTRICAL SCIENCE

A REPRINT OF THE CHAPTER ON ELECTRICS FROM
DE MAGNETE, LIB. 2

WITH NOTES BY

SILVANUS P. THOMPSON, F.R.S.

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Gilbert shall live till loadstones cease to draw,
Or British fleets the boundless Ocean awe.

DRYDEN.

GILBERT OF COLCHESTER

Father of Electrical Science.

BY the publication in 1600 of the *De Magnete* of Dr. William Gilbert the science of electricity was founded. To-day, December 10th, 1903, is the three-hundredth anniversary of his death.

Born in Colchester on May 24th, 1544, William Gilbert was educated at Colchester School, and at St. John's College, Cambridge, where he became mathematical examiner and senior bursar. He graduated M.D. in 1569, and after three years of travel and study in Italy and elsewhere, settled down in London as a physician in 1573. He rose rapidly to eminence in his profession, and for twenty years took an active part in the administration of the Royal College of Physicians, of which in 1599 he became President. He was also in favour at Court, and was appointed in February, 1600-1, Physician to Queen Elizabeth, who conferred upon him various marks of distinction; and after her death he was continued as Chief Physician by James I. He died during a visitation of the plague, December 10th, 1603, and was buried in the Church of Holy Trinity, Colchester, where there is a monumental tablet to his memory.

Gilbert's renown rests not on his eminence as a physician, but on his achievements in the foundation of the twin sciences of electricity and magnetism. He is beyond question rightfully regarded as the Father of Electric Science. He founded the entire subject of

Terrestrial Magnetism. He also made notable contributions to Astronomy, being the earliest English expounder of Copernicus. In an age given over to metaphysical obscurities and dogmatic sophistry, he cultivated the method of experiment and of reasoning from observation, with an insight and success which entitles him to be regarded as the father of the inductive method. That method, so often accredited to Bacon, Gilbert was practising years before him.

It seems therefore fitting upon the occurrence of the Tercentenary of his death to recall Gilbert's achievements as the Father of Electric Science.

GILBERT'S MAGNETIC DISCOVERIES.

ILBERT'S magnetic work has been so often described that a brief summary will here suffice. Trying the properties of loadstones in innumerable experiments lasting over many years, he was led to several notable discoveries, and to one generalization of immense importance. He discovered the augmentation of the power of a loadstone by arming or capping it with soft iron cheeks. Gilbert called such a cap an *armatura*, the first occurrence of the term. This invention brought him much fame. In the *Dialogues of Galileo* (p. 369 of Salusbury's *Mathematical Collections*, Dialogue iii.), Sagredus and Salviatus discuss the arming of the loadstone, and the increased lifting power conferred by adding an iron cap. Salviatus mentions a loadstone in the Florentine Academy which, unarmed, weighed six ounces, lifting only two ounces, but which when armed took up 160 ounces. Whereupon Galileo makes Salviatus say: "I extreamly praise, admire, and envy this Authour, for that a conceit so stupendious should come into his minde. . . . I think him [*i.e.*, Gilbert] moreover worthy of extraordinary applause for the many new and true Observations that he made, to the disgrace of so many fabulous Authours, that write not only what they do not know, but whatever they hear spoken by the foolish vulgar, never seeking to assure themselves of the same

by experience, perhaps, because they are unwilling to diminish the bulk of their Books."

Gilbert also discovered the screening effect of a sheet of iron; the method of magnetizing iron by hammering it while it lies North and South; the destruction of magnetism by heat; and the existence around the magnet of an "orbe of virtue," that is to say, a magnetic field. He perfected the dipping-needle of Norman, and other instruments of observation. He collected data as to the declination and inclination of the compass in different regions. Using loadstones of many different shapes he observed their actions on one another and on compass-needles. In particular he studied the magnetic properties of a globular loadstone or *terrella*, and found that compass-needles were directed toward its poles, and dipped at various angles over its surface, just as compass-needles do at various regions of the earth's surface.

Generalizing from small to large he advanced the entirely novel idea that the globe of the earth is itself a great magnet; thus laying the foundations of the science of terrestrial magnetism. He was particularly keen in disproving the many absurd fables that had grown up about the magnet, such as that the magnet refuses to act in the presence of a diamond, or if touched with garlic. The former he tested by surrounding a loadstone with seventy diamonds. Gilbert denounced the quackery of using loadstone medicinally or in plasters for the cure of wounds. He ridiculed the idea that the variation of the compass was due to imaginary loadstone-mountains like those described in the Arabian Nights. He sought to explain it by the local irregularities of the earth's crust, and exemplified his theory by experiments on round loadstones of irregular outline as models. His book, over which he spent eighteen years, was published in 1600, and for the next hundred years became the standard work on magnetism. Though denounced by the Church, the theory of terrestrial magnetism was by Gilbert thus firmly established on an enduring basis of fact, and remained a permanent acquisition in science. The publication of the book marked an epoch in scientific development. It was praised by Sarpi, by Galileo, by Kepler. Sir Christopher Wren proposed to erect a statue to its author, while Dryden sang of his enduring fame.

THE ELECTRICAL KNOWLEDGE OF THE ANCIENTS.

PRIOR to Gilbert's time the only electrical phenomenon known generally was the simple fact that the minerals amber and jet, when rubbed, will attract light bodies. This property of amber was indeed known to the ancients, and is mentioned by Theophrastus. The following quotations from early writers include practically all that was known.

"Hee [*Niceas*] writeth also, that in Aegypt it [amber] is engendered . . . Semblably in Syria, the women (saith hee) make wherves of it for their spindles, where they use to call it Harpax, because it will catch up leaves, straws, and fringes hanging to cloaths. . . . To come to the properties that Amber hath, If it bee well rubbed and chaufed betwene the fingers, the potentiall facultie that lieth within, is set on work, and brought into actual operation, whereby you shall see it to drawe chaffe strawes, drie leaves, yea, and thin rinds of the Linden or Tillet tree, after the same sort as loadstone draweth yron" (Pliny, *Natural History*, book xxxvii., chap. ii., p. 606 of the English version of 1601).

"Moreover to the intent to passe the large aboundance of sundry mettals (whereof Britaine hath many rich mynes on all sides), Here is store of the stone called Geate, and y^e^ best kind of it. If ye demaund y^e^ beautie of it, it is a black Jewell: if the qualitie, it is of no weight: if the nature, it burneth in water, and goeth out in Oyle; if the power, rubbe it till it be warme, and it holdeth such things as are laide to it; as Amber doth. The Realme is partlie inhabited of barbarous people, who even frõ theyr childhoode haue shapes of divers beastes cunninglye impressed and incorporate in theyr bodyes, so that beeing engraued as it were in theyr bowels, as the man groweth, so growe the marks painted vpon him" (Julius Solinus, *The Secretes and Providence of Nature*, chap. xxiv., *Of Britaine;* English version by A. Golding, 1587).

GILBERT'S CHAPTER ON ELECTRICS.

The contribution made by Gilbert to electrical knowledge is contained in the second chapter of the second book of his *De Magnete*, and constitutes a digression interpolated into the discussion of magnetic motions. Later portions of the same book make slight references also to the subject: but all that is essential in Gilbert's work is in this single chapter, here reprinted from the English Edition of 1900, the version prepared by the Gilbert Club.

BOOK II., CHAPTER II.

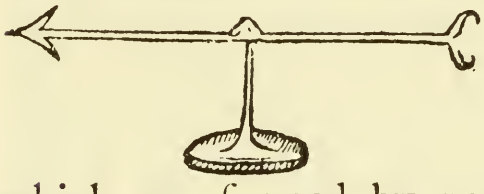
On the Attraction of Amber, or more truly, on the *Attaching of Bodies to Amber*.

ELEBRATED has the fame of the loadſtone and of amber ever been in the memoirs of the learned. Loadſtone and alſo amber do ſome philoſophers invoke when in explaining many ſecrets their ſenſes become dim and reaſoning cannot go further. Inquiſitive theologians alſo would throw light on the divine myſteries ſet beyond the range of human ſenſe, by means of loadſtone and amber; juſt as idle Metaphyſicians, when they are ſetting up and teaching uſeleſs phantaſms, have recourſe to the loadſtone as if it were a Delphick ſword, an illuſtration always applicable to everything. But phyſicians even (with the authority of Galen), deſiring to confirm the belief in the attraction of purgative medicines by means of the likeneſs of ſubſtance and the familiarities of the juices—truly a vain and uſeleſs error—bring in the loadſtone as witneſs as being a nature of great authority and of conſpicuous efficacy and a remarkable body. So in very many caſes there are ſome who, when they are pleading a cauſe and cannot give a reaſon for it, bring in loadſtone and amber as though they were perſonified witneſſes. But theſe men (apart from that common error) being ignorant that the cauſes of magnetical motions are widely different from the forces of amber, eaſily fall into error, and are themſelves the more deceived by their own cogitations. For in other bodies a conſpicuous force of attraction manifeſts itſelf otherwiſe than in loadſtone; like as in amber, concerning which ſome things muſt firſt be ſaid, as to what is that attaching of bodies to it, and how different from and foreign to the magnetical actions; thoſe mortals being ſtill ignorant, who think

that inclination to be an attraction, and compare it with the magnetick coitions. The Greeks call it ἤλεκτρον, because it attracts straws to itself, when it is warmed by rubbing; then it is called ἅρπαξ; and χρυσοφόρον, from its golden colour. But the Moors call it Carabe, becauſe they are accuſtomed to offer the ſame in ſacrifices and in the worſhip of the Gods. For Carab ſignifies to offer in Arabic; ſo Carabe, an offering: or ſeizing chaff, as Scaliger quotes from Abohalis, out of the Arabic or Perſian language. Some alſo call it Amber, eſpecially the Indian and Ethiopian amber, called in Latin *Succinum*, as if it were a juice. The Sudavienſes or Sudini call it *geniter*, as though it were generated terreſtrially. The errors of the ancients concerning its nature and origin having been exploded, it is certain that amber comes for the moſt part from the ſea, and the ruſtics collect it on the coaſt after the more violent ſtorms, with nets and other tackle; as among the Sudini of Pruſſia; and it is alſo found ſometimes on the coaſt of our own Britain. It ſeems, however, to be produced alſo in the ſoil and at ſpots of ſome depth, like other bitumens; to be waſhed out by the waves of the ſea; and to become concreted more firmly from the nature and ſaltneſs of the ſea-water. For it was at firſt a ſoft and viſcous material; wherefore alſo it contains encloſed and entombed in pieces of it, ſhining in eternal ſepulchres, flies, grubs, gnats, ants; which have all flown or crept or fallen into it when it firſt flowed forth in a liquid ſtate. The ancients and alſo more recent writers recall (experience proving the ſame thing), that amber attracts straws and chaff. The ſame is alſo done by jet, which is dug out of the earth in Britain, in Germany, and in very many lands, and is a rather hard concretion from black bitumen, and as it were a transformation into ſtone. There are many modern authors who have written and copied from others about amber and jet attracting chaff, and about other ſubſtances generally unknown; with whoſe labours the ſhops of bookſellers are crammed. Our own age has produced many books about hidden, abſtruſe, and occult cauſes and wonders, in all of which amber and jet are ſet forth

as enticing chaff; but they treat the ſubject in words alone, without finding any reaſons or proofs from experiments, their very ſtatements obſcuring the thing in a greater fog, forſooth in a cryptic, marvellous, abſtruſe, ſecret, occult, way. Wherefore alſo ſuch philoſophy produces no fruit, becauſe very many philoſophers, making no inveſtigation themſelves, unſupported by any practical experience, idle and inert, make no progreſs by their records, and do not ſee what light they can bring to their theories; but their philoſophy reſts ſimply on the uſe of certain Greek words, or uncommon ones; after the manner of our goſſips and barbers nowadays, who make ſhow of certain Latin words to an ignorant populace as the inſignia of their craft, and ſnatch at the popular favour. For it is not only amber and jet (as they ſuppoſe) which entice ſmall bodies; but Diamond, ✶
Sapphire, Carbuncle, Iris gem, Opal, Amethyſt, Vincentina, and Briſtolla (an English gem or ſpar), Beryl, and Cryſtal do the ſame. Similar powers of attraction are ſeen alſo to be poſſeſſed by glaſs (eſpecially when clear and lucid), as alſo by falſe gems made of glaſs or Cryſtal, by glaſs of antimony, and by many kinds of ſpars from the mines, and by Belemnites. Sulphur alſo attracts, and maſtick, and hard ſealing-wax compounded of lac tinctured of various colours. Rather hard reſin entices, as does orpiment, but leſs ſtrongly; with difficulty alſo and indiſtinctly under a ſuitable dry ſky, Rock ſalt, muſcovy ſtone, and rock alum. This one may ſee when the air is ſharp and clear and rare in mid-winter, when the emanations from the earth hinder electricks leſs, and the electrick bodies become more firmly indurated; about which hereafter. Theſe ſubſtances draw every- ✶
thing, not ſtraws and chaff only, but all metals, woods, leaves, ſtones, earths, even water and oil, and everything which is ſubject to our ſenſes, or is ſolid; although there are who write that amber does not attract anything but chaff and certain twigs; (wherefore Alexander Aphrodiſeus falſely declares the queſtion of amber to be inexplicable, becauſe it attracts dry chaff only, and not baſil leaves). But theſe are the utterly falſe and diſgrace-

ful tales of the writers. But in order that you may be able clearly to teſt how ſuch attraction occurs, and what thoſe materials are which thus entice other bodies (for even if bodies incline towards ſome of theſe, yet on account of weakneſs they ſeem not to be raiſed by them, but are more eaſily turned), make yourſelf a verſorium of any metal you like, three or four digits in length, reſting rather lightly on its point of ſupport after the manner of a magnetick needle, to one end of which bring up a piece of amber or a ſmooth and poliſhed gem which has been gently rubbed; for the verſorium turns forthwith. Many things are thereby ſeen to attract, both thoſe which are formed by nature alone, and thoſe which are by art prepared, fuſed, and mixed; nor is this ſo much a ſingular property of one or two things (as is commonly ſuppoſed), but the manifeſt nature of very many, both of ſimple ſubſtances, remaining merely in their own form, and of compoſitions, as of hard ſealing-wax, and of certain other mixtures beſides, made of unctuous ſtuffs. We muſt, however, inveſtigate more fully whence that tendency, and what thoſe forces, concerning which a few men have brought forward very little, the crowd of philoſophizers nothing at all. By Galen three kinds of attractives in general were recognized in nature: a Firſt claſs of thoſe ſubſtances which attract by their elemental quality, namely, heat; the Second is the claſs of thoſe which attract by the ſucceſſion of a vacuum; the Third is the claſs of thoſe which attract by a property of their whole ſubſtance, which are alſo quoted by Avicenna and others. Theſe claſſes, however, cannot in any way ſatisfy us; they neither embrace the cauſes of amber, jet, and diamond, and of other ſimilar ſubſtances (which derive their forces on account of the ſame virtue); nor of the loadſtone, and of all magnetick ſubſtances, which obtain their virtue by a very diſſimilar and alien influence derived from other ſources. Wherefore alſo it is fitting that we find other cauſes of the motions, or elſe we muſt wander (as in the ſhades), with theſe men, and in no way



reach the goal. Amber truly does not allure by heat, ✱
ſince if warmed by fire and brought near ſtraws, it does not attract them, whether it be tepid, or hot, or glowing, or even when forced into the flame. Cardan (as alſo Pictorio) reckons that this happens in no different way than with the cupping-glaſs, by the force of fire. Yet the attracting force of the cupping-glass does not really come from the force of fire. But he had previouſly ſaid that the dry ſubſtance wiſhed to imbibe fatty humour, and therefore it was borne towards it. But theſe ſtatements are at variance with one another, and alſo foreign to reaſon. For if amber had moved towards its food, or if other bodies had inclined towards amber as towards provender, there would have been a diminution of the one which was devoured, juſt as there would have been a growth of the other which was fated. Then why ſhould an attractive force of fire be looked for in amber? If the attraction exiſted from heat, why ſhould not very many other bodies alſo attract, if warmed by fire, by the ſun, or by friction? Neither can the attraction be on account of the diſſipating of the air, when it takes place in open air (yet Lucretius the poet adduces this as the reaſon for magnetical motions). Nor in the cupping-glaſs can heat or fire attract by feeding on air: in the cupping-glaſs air, having been exhauſted into flame, when it condenſes again and is forced into a narrow ſpace, makes the ſkin and fleſh riſe in avoiding a vacuum. In the open air warm things cannot attract, not metals even or ſtones, if they ſhould be ſtrongly incandeſcent by fire. For a ✱
rod of glowing iron, or a flame, or a candle, or a blazing torch, or a live coal, when they are brought near to ſtraws, or to a verſorium, do not attract; yet at the ſame time they manifeſtly call in the air in ſucceſſion; becauſe they conſume it, as lamps do oil. But concerning heat, how it is reckoned by the crowd of philoſophizers, in natural philoſophy and in *materia medica* to exert an attraction otherwiſe than nature allows, to which true attractions are falſely imputed, we will diſcuſs more at length elſewhere, when we ſhall determine what are the properties of heat and cold. They are very general

qualities or kinſhips of a ſubſtance, and yet are not to be aſſigned as true cauſes, and, if I may ſay ſo, thoſe philoſophizers utter ſome reſounding words; but about the thing itſelf prove nothing in particular. Nor does this attraction accredited to amber ariſe from any ſingular quality of the ſubſtance or kinſhip, ſince by more thorough reſearch we find the ſame effect in very many other bodies; and all bodies, moreover, of whatever quality, are allured by all thoſe bodies. Similarity alſo is not the cauſe; becauſe all things around us placed on this globe of the earth, ſimilar and diſſimilar, are allured by amber and bodies of this kind; and on that account no cogent analogy is to be drawn either from ſimilarity or identity of ſubſtance. But neither do ſimilars mutually attract one another, as ſtone ſtone, fleſh fleſh, nor aught elſe outſide the claſs of magneticks and electricks. Fracaſtorio would have it that "things which mutually attract one another "are ſimilars, as being of the ſame ſpecies, either in action "or in right ſubjection. Right ſubjection is that from "which is emitted the emanation which attracts and which "in mixtures often lies hidden on account of their lack "of form, by reaſon of which they are often different in "act from what they are in potency. Hence it may be "that hairs and twigs move towards amber and towards "diamonds, not becauſe they are hairs, but becauſe either "there is ſhut up in them air or ſome other principle, "which is attracted in the firſt place, and which bears "ſome relation and analogy to that which attracts of itſelf; "in which diamond and amber agree through a principle "common to each." Thus far Fracaſtorio. Who if he had obſerved by a large number of experiments that all bodies are drawn to electricks except thoſe which are aglow and aflame, and highly rarefied, would never have given a thought to ſuch things. It is eaſy for men of acute intellect, apart from experiments and practice, to ſlip and err. In greater error do they remain ſunk who maintain theſe ſame ſubſtances to be not ſimilar, but to be ſubſtances near akin; and hold that on that account a thing moves towards another, its like, by which it is brought to more perfection. But theſe are ill-conſidered views; for

towards all electricks all things move except ſuch as are aflame or are too highly rarefied, as air, which is the univerſal effluvium of this globe and of the world. Vegetable ſubſtances draw moiſture by which their ſhoots are rejoiced and grow; from analogy with that, however, Hippocrates, in his *De Natura Hominis*, Book I., wrongly concluded that the purging of morbid humour took place by the ſpecifick force of the drug. Concerning the action and potency of purgatives we ſhall ſpeak elſewhere. Wrongly alſo is attraction inferred in other effects; as in the caſe of a flagon full of water, when buried in a heap of wheat, although well ſtoppered, the moiſture is drawn out; ſince this moiſture is rather reſolved into vapour by the emanation of the fermenting wheat, and the wheat imbibes the freed vapour. Nor do elephant's tuſks attract moiſture, but drive it into vapour or abſorb it. Thus then very many things are ſaid to attract, the reaſons for whoſe energy muſt be ſought from other cauſes. Amber in a fairly large maſs * allures, if it is poliſhed; in a ſmaller maſs or leſs pure it ſeems not to attract without friction. But very many electricks (as precious ſtones and ſome other ſubſtances) do not attract at all unleſs rubbed. On the other hand many gems, as well as other bodies, are poliſhed, yet do not allure, and by no amount of friction are they arouſed; thus the emerald, agate, carnelian, pearls, jaſper, chalce- * dony, alabaſter, porphyry, coral, the marbles, touchſtone, flint, bloodſtone, emery, do not acquire any power; nor do bones, or ivory, or the hardeſt woods, as ebony, nor do cedar, juniper, or cypreſs; nor do metals, ſilver, gold, braſs, iron, nor any loadſtone, though many of them are finely poliſhed and ſhine. But on the other hand there are ſome other poliſhed ſubſtances of which we have ſpoken before, toward which, when they have been rubbed, bodies incline. This we ſhall underſtand only when we have more cloſely looked into the prime origin of bodies. It is plain to all, and all admit, that the maſs of the earth, or rather the ſtructure and cruſt of the earth, conſiſts of a twofold material, namely, of fluid and humid matter, and of material of more con-

ſiſtency and dry. From this twofold nature or the more ſimple compacting of one, various ſubſtances take their riſe among us, which originate in greater proportion now from the earthy, now from the aqueous nature. Thoſe ſubſtances which have received their chief growth from moiſture, whether aqueous or fatty, or have taken on their form by a ſimpler compacting from them, or have been compacted from theſe ſame materials in long ages, if they have a ſufficiently firm hardneſs, if rubbed after they have been poliſhed and when they remain bright with the friction—towards thoſe ſubſtances everything, if preſented to them in the air, turns, if its too heavy weight does not prevent it. For amber has been compacted of moiſture, and jet alſo. Lucid gems are made of water; juſt as Cryſtal, which has been concreted from clear water, not always by a very great cold, as ſome uſed to judge, and by very hard froſt, but ſometimes by a leſs ſevere one, the nature of the ſoil faſhioning it, the humour or juices being ſhut up in definite cavities, in the way in which ſpars are produced in mines. So clear glaſs is fuſed out of ſand, and from other ſubſtances, which have their origin in humid juices. But the droſs of metals, as alſo metals, ſtones,
* rocks, woods, contain earth rather, or are mixed with a good deal of earth; and therefore they do not attract. Cryſtal, mica, glaſs, and all electricks do not attract if they are burnt or roaſted; for their primordial ſupplies of moiſture periſh by heat, and are changed and exhaled. All things therefore which have ſprung from a predominant moiſture and are firmly concreted, and retain the appearance of ſpar and its reſplendent nature in a firm and compact body, allure all bodies, whether humid or dry. Thoſe, however, which partake of the true earth-ſubſtance or are very little different from it, are ſeen to attract alſo, but from a far different reaſon, and (ſo to ſay) magnetically; concerning theſe we intend to ſpeak afterwards. But thoſe ſubſtances which are more mixed of water and earth, and are produced by the equal degradation of each element (in which the magnetick force of the earth is deformed and remains

buried; while the watery humour, being fouled by joining with a more plentiful ſupply of earth, has not concreted in itſelf but is mingled with earthy matter), can in no way of themſelves attract or move from its place anything which they do not touch. On this account metals, marbles, flints, woods, herbs, fleſh, and very many other things can neither allure nor ſolicit any body either magnetically or electrically. (For it pleaſes us to call that an electrick force, which hath its origin from the humour). But ſubſtances conſiſting moſtly of humour, and which are not very firmly compacted * by nature (whereby alſo they do not bear rubbing, but either melt down and become ſoft, or are not levigable, ſuch as pitch, the ſofter kinds of reſin, camphor, galbanum, ammoniack, ſtorax, aſafœtida, benzoin, aſphaltum, eſpecially in rather warm weather) towards them ſmall bodies are not borne; for without rubbing moſt * electricks do not emit their peculiar and native exhalation and effluvium. The reſin turpentine when liquid does not attract; for it cannot be rubbed; but if it has hardened into a mastick it does attract. But now at length we muſt underſtand why ſmall bodies turn towards thoſe ſubſtances which have drawn their origin from water; by what force and with what hands (ſo to ſpeak) electricks ſeize upon kindred natures. In all bodies in the world two cauſes or principles have been laid down, from which the bodies themſelves were produced, matter and form. Electrical motions become ſtrong from matter, but magnetick from form chiefly; and they differ widely from one another and turn out unlike, ſince the one is ennobled by numerous virtues and is prepotent; the other is ignoble and of leſs potency, and moſtly reſtrained, as it were, within certain barriers; and therefore that force muſt at times be arouſed by attrition or friction, until it is at a dull heat and gives off an effluvium and a poliſh is induced on the body. For ſpent air, either blown out of the mouth or given * off from moiſter air, chokes the virtue. If indeed either a ſheet of paper or a piece of linen be interpoſed, there will be no movement. But a loadſtone, on the other

hand, without friction or heat, whether dry or ſuffuſed with moiſture, as well in air as in water, invites magneticks, and attracts them even with the moſt ſolid bodies interpoſed, even planks of wood or pretty thick
* ſlabs of ſtone or ſheets of metal. A loadſtone appeals to magneticks only; towards electricks all things move. A loadſtone raiſes great weights; ſo that if there is a loadſtone weighing two ounces and ſtrong, it attracts half an ounce or a whole ounce. An electrical ſubſtance only attracts very ſmall weights; as, for inſtance, a piece of amber of three ounces weight, when rubbed, ſcarce raiſes a fourth part of a grain of barley. But this attraction of amber and of electrical ſubſtances muſt be further inveſtigated; and ſince there is this particular affection of matter, it may be aſked why is amber rubbed, and what affection is produced by the rubbing, and what cauſes ariſe which make it lay hold on everything? As a reſult of friction it grows ſlightly warm and becomes ſmooth; two reſults which muſt often occur together. A large poliſhed fragment of amber or jet attracts indeed, even without friction, but leſs ſtrongly; but if it be brought gently near a flame or a live coal, ſo that it equally becomes warm, it does not
* attract ſmall bodies becauſe it is enveloped in a cloud from the body of the flaming ſubſtance, which emits a hot breath, and then impinges upon it vapour from a foreign body which for the moſt part is at variance with the nature of amber. Moreover the ſpirit of the amber which is called forth is enfeebled by alien heat; wherefore it ought not to have heat excepting that produced by motion only and friction, and, as it were, its own, not ſent into it by other bodies. For as the igneous heat emitted from any burning ſubſtance cannot be ſo uſed that electricks may acquire their force from
* it; ſo alſo heat from the ſolar rays does not fit an electrick by the looſening of its right material, because it diſſipates rather and conſumes it (albeit a body which has been rubbed retains its virtue longer expoſed to the rays of the ſun than in the ſhade; becauſe in the ſhade the effluvia are condenſed to a greater degree and more

quickly). Then again the fervour from the light of the Sun arouſed by means of a burning mirror confers no * vigour on the heated amber; indeed it diſſipates and corrupts all the electrick effluvia. Again, burning ſul- * phur and hard wax, made from ſhell-lac, when aflame do not allure; for heat from friction reſolves bodies into effluvia, which flame conſumes away. For it is impoſſible for ſolid electricks to be reſolved into their own true effluvia otherwiſe than by attrition, ſave in the caſe of certain ſubſtances which by reaſon of innate vigour emit effluvia conſtantly. They are rubbed with bodies which do not befoul their ſurface, and which produce a poliſh, as pretty ſtiff ſilk or a rough wool rag which is as little ſoiled as poſſible, or the dry palm. Amber alſo is rubbed with amber, with diamond, and with glaſs, and numerous other ſubſtances. Thus are electricks manipulated. Theſe things being ſo, what is it which moves? Is it the body itſelf, incloſed within its own circumference? Or is it ſomething imperceptible to us, which flows out from the ſubſtance into the ambient air? Somewhat as Plutarch opines, ſaying in his *Quæſtiones Platonicæ*: That there is in amber ſomething flammable or ſomething having the nature of breath, and this by the attrition of the ſurface, being emitted from its relaxed pores, attracts bodies. And if it be an effuſion does it ſeize upon the air whoſe motion the bodies follow, or upon the bodies themſelves? But if amber allured the body itſelf, then what need were there of friction, if it is bare and ſmooth? Nor does the force ariſe from the light which is reflected from a ſmooth and poliſhed body; for the Gem of Vincent's rocks, Diamond, and clear glaſs, attract when they are rough; but not ſo powerfully and quickly, becauſe they are not ſo readily cleanſed from extraneous moiſture on the ſurface, and are not rubbed equally ſo as to be copiouſly reſolved at that part. Nor does the ſun by its own beams of light and its rays, which are of capital importance in nature, attract bodies in this way; and yet the herd of philoſophizers conſiders that humours are attracted by the ſun, when it is only denſer humours

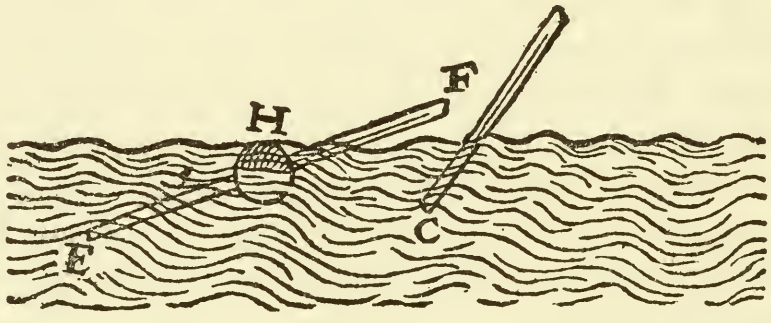
that are being turned into thinner, into ſpirit and air; and ſo by the motion of effuſion they aſcend into the upper regions, or the attenuated exhalations are raiſed up from the denſer air. Nor does it ſeem to take place from the effluvia attenuating the air, ſo that bodies impelled by the denſer air penetrate towards the ſource of the rarefaction; in this caſe both hot and flaming bodies would alſo allure other bodies; but not even the lighteſt chaff, or any verſorium moves towards a flame. If there is a flow and ruſh of air towards the body, how can a ſmall diamond of the ſize of a pea ſummon towards itſelf ſo much air, that it ſeizes hold of a biggiſh long body placed in equilibrio (the air about one or other very ſmall part of an end being attracted)? It ought alſo to have ſtopped or moved more ſlowly, before it came into contact with the body, eſpecially if the piece of amber was rather broad and flat, from the accumulation of air on the ſurface of the amber and its flowing back again. If it is becauſe the effluvia are thinner, and denſer vapours come in return, as in breathing, then the body would rather have had a motion toward the electrick a little while after the beginning of the application; but when electricks which have been rubbed are applied quickly to a verſorium then eſpecially
* at once they act on the verſorium, and it is attracted more when near them. But if it is becauſe the rarefied effluvia make a more rarefied medium, and on that account bodies are more prone to ſlip down from a denſer to a more attenuated medium; they might have been carried from the ſide in this way or downwards, but not to bodies above them; or the attraction and apprehenſion of contiguous bodies would have been momentary only. But with a ſingle friction jet and amber draw and attract bodies to them ſtrongly and for a long time, ſometimes for the twelfth part of an hour, eſpecially in clear weather. But if the maſs of amber be rather large, and the ſurface poliſhed, it attracts without friction. Flint is rubbed and emits by attrition an inflammable matter that turns into ſparks and heat. Therefore the denſer effluvia of flint producing fire are very far different from electrical

effluvia, which on account of their extreme attenuation do not take fire, nor are fit material for flame. Thoſe effluvia are not of the nature of breath, for when emitted they do not propel anything, but are exhaled without ſenſible reſiſtance and touch bodies. They are highly attenuated humours much more ſubtile than the ambient air; and in order that they may occur, bodies are required produced from humour and concreted with a conſiderable degree of hardneſs. Non-electrick bodies are not reſolved into humid effluvia, and thoſe effluvia mix with the common and general effluvia of the earth, and are not peculiar. Alſo beſides the attraction of bodies, they retain them longer. It is probable therefore that amber * does exhale ſomething peculiar to itſelf, which allures bodies themſelves, not the intermediate air. Indeed it plainly does draw the body itſelf in the caſe of a ſpherical drop of water ſtanding on a dry ſurface; for a piece of amber applied to it at a ſuitable diſtance pulls the nearеſt parts out of their poſition and draws it up into a cone; otherwiſe, if it were drawn by means of the air * ruſhing along, the whole drop would be moved. That it does not attract the air is thus demonſtrated: take a very thin wax candle, which makes a very ſmall and clear flame; bring up to this, within two digits or any convenient diſtance, a piece of amber or jet, a broad flat * piece, well prepared and ſkilfully rubbed, ſuch a piece of amber as would attract bodies far and wide, yet it does not diſturb the flame; which of neceſſity would have occurred, if the air was diſturbed, for the flame would have followed the current of air. As far as the effluvia are ſent out, ſo far it allures; but as a body approaches, its motion is accelerated, ſtronger forces drawing it; as alſo in the caſe of magneticks and in all natural motion; not by attenuating or by expelling the air, ſo that the body moves down into the place of the air which has gone out; for thus it would have allured only and would not have retained; ſince it would at firſt alſo have repelled approaching bodies juſt as it drives the air itſelf; but indeed a particle, be it ever ſo ſmall, does not avoid the firſt application made very quickly after rubbing.

An effluvium exhales from amber and is emitted by rubbing: pearls, carnelian, agate, jaſper, chalcedony, coral, metals, and other ſubſtances of that kind, when they are rubbed, produce no effect. Is there not alſo ſomething which is exhaled from them by heat and attrition? Moſt truly; but from groſſer bodies more blended with the earthy nature, that which is exhaled is groſs
* and ſpent; for even towards very many electricks, if they are rubbed too hard, there is produced but a weak attraction of bodies, or none at all; the attraction is beſt when the rubbing has been gentle and very quick; for ſo the fineſt effluvia are evoked. The effluvia ariſe from the ſubtile diffuſion of humour, not from exceſſive and turbulent violence; eſpecially in the caſe of thoſe ſubſtances which have been compacted from unctuous matter, which when the atmoſphere is very thin, when the North winds, and amongſt us (Engliſh) the Eaſt winds, are blowing, have a ſurer and firmer effect, but during
* South winds and in damp weather, only a weak one; ſo that thoſe ſubſtances which attract with difficulty in clear weather, in thick weather produce no motion at all; both becauſe in groſſer air lighter ſubſtances move with greater difficulty; and eſpecially becauſe the effluvia are ſtifled, and the ſurface of the body that has been rubbed is affected by the ſpent humour of the air, and the effluvia are ſtopped at their very ſtarting. On that account in the caſe of amber, jet, and ſulphur, becauſe they do not ſo eaſily take up moiſt air on their ſurface and are much more plenteouſly ſet free, that force is not ſo quickly ſuppreſſed as in gems, cryſtal, glaſs, and ſubſtances of that kind which collect on their ſurface the moiſter breath which has grown heavy. But it may be aſked why does amber allure water, when water placed on its ſurface removes its action? Evidently becauſe it
* is one thing to ſuppreſs it at its very ſtart, and quite another to extinguiſh it when it has been emitted. So alſo thin and very fine ſilk, in common language *Sarce-*
* *net*, placed quickly on the amber, after it has been rubbed, hinders the attraction of the body; but if it is interpoſed in the intervening ſpace, it does not entirely

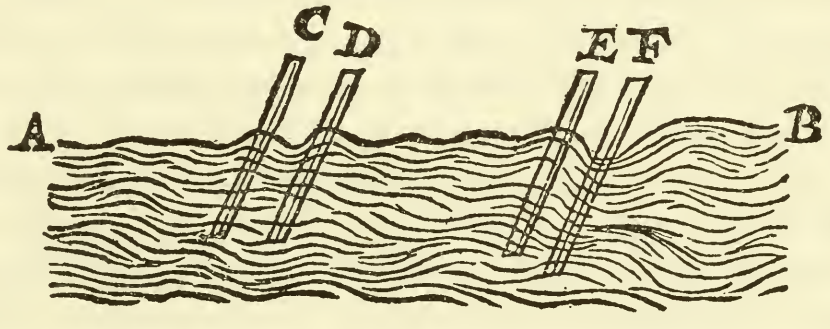
obſtruct it. Moiſture alſo from ſpent air, and any breath blown from the mouth, as well as water put on the amber, immediately extinguiſhes its force. But oil, * which is light and pure, does not hinder it; for although amber be rubbed with a warm finger dipped in oil, ſtill * it attracts. But if that amber, after the rubbing, is moiſtened with *aqua vitæ* or ſpirits of wine, it does not attract; for it is heavier than oil, denſer, and when added to oil ſinks beneath it. For oil is light and rare, and does not reſiſt the moſt delicate effluvia. A breath therefore, proceeding from a body which had been compacted from humour or from a watery liquid, reaches the body to be attracted; the body that is reached is united with the attracting body, and the one body lying near the other within the peculiar radius of its effluvia makes one out of two; united, they come together into the cloſeſt accord, and this is commonly called attraction. This unity, according to the opinion of Pythagoras, is the principle of all things, and through participation in it each ſeveral thing is ſaid to be one. For ſince no action can take place by means of matter unleſs by contact, theſe electricks are not ſeen to touch, but, as was neceſſary, ſomething is ſent from the one to the other, ſomething which may touch cloſely and be the beginning of that incitement. All bodies are united and, as it were, cemented together in ſome way by moiſture; ſo that a wet body, when it touches another body, attracts it, if it is ſmall. So wet bodies on the ſurface of water attract wet bodies. But the peculiar electrical effluvia, which are the moſt ſubtile material of diffuſe humour, entice corpuſcles. Air (the common effluvium of the earth) not only unites the disjointed parts, but the earth calls bodies back to itſelf by means of the intervening air; otherwiſe bodies which are in higher places would not ſo eagerly make for the earth. Electrical effluvia differ greatly from air; and as air is the effluvium of the earth, ſo electricks have their own effluvia and properties, each of them having by reaſon of its peculiar effluvia a ſingular tendency toward unity, a motion toward its origin and fount, and toward the body emitting the

effluvia. But thoſe ſubſtances which by attrition emit a groſs or vapourous or aeriform effluvium produce no effect: for either ſuch effluvia are alien to the humour (the uniter of all things), or being very like common air are blended with the air and intermingle with the air, wherefore they produce no effect in the air, and do not cauſe motions different from thoſe ſo univerſal and com-
* mon in nature. In like manner bodies ſtrive to be united and move on the ſurface of water, juſt as the rod C, which is put a little way under water. It is plain that the rod E F, which floats on the water by reaſon of the cork H, and only has its wet end F above the ſurface of the water, is attracted by the rod C, if the rod C is wet a little above the ſurface of the water; they are ſuddenly united, juſt as a drop adjoining a drop is at-



tracted. So a wet thing on the ſurface of water ſeeks union with a wet thing, ſince the ſurface of the water is raiſed on both; and they immediately flow together, juſt like drops or bubbles. But they are in much greater proximity than electricks, and are united by their
* clammy natures. If, however, the whole rod be dry above the water, it no longer attracts, but drives away the ſtick E F. The ſame is ſeen in thoſe bubbles alſo which are made on water. For we ſee one drive towards another, and the quicker the nearer they are. Solids are impelled towards ſolids by the medium of liquid: for example, touch the end of a verſorium with the end of a rod on which a drop of water is projecting; as ſoon
* as the verſorium touches the top of the droplet, immediately it is joined ſtrongly by a ſwift motion to the body of the rod. So concreted humid things attract when a little reſolved into air (the effluvia in the intermediate

ſpace tending to produce unity); for water has on wet bodies, or on bodies wet with abundant moiſture on the top of water, the force of an effluvium. Clear air is a convenient medium for an electrical effluvium excited from concreted humour. Wet bodies projecting above the ſurface of water (if they are near) run together ſo that they may unite; for the ſurface of the water is raiſed around wet ſubſtances. But a dry thing is not impelled to a wet one, nor a wet to a dry, but ſeems to run away. For if all is dry above the water, the ſurface of the water cloſe to it does not riſe, but ſhuns it, the wave ſinking around a dry thing. So neither does a wet thing move towards the dry rim of a veſſel; but it ſeeks a wet rim. A B is the ſurface of the water; C D two rods, which ſtand up wet above the water; it is manifeſt that



the ſurface of the water is raiſed at C and D along with the rods; and therefore the rod C, by reaſon of the water ſtanding up (which ſeeks its level and unity), moves with the water to D. On E, on the other hand, a wet rod, the water alſo riſes; but on the dry rod F the ſurface is depreſſed; and as it ſtrives to depreſs alſo the wave riſing on E in its neighbourhood, the higher wave at E turns away from F; for it does not ſuffer itſelf to be depreſſed. All electrical attraction exiſts through an intervening humour; ſo it is by reaſon of humour that all things mutually come together; fluids indeed and aqueous bodies on the ſurface of water, but concreted things, if they have been reſolved into vapour, in air;—in air indeed, the effluvium of electricks being very rare, that it may the better permeate the medium and not impel it by its motion; for if that effluvium had been thick, as that of air, or of the winds, or of ſaltpetre burnt by fire, as

the thick and foul effluvia given out with very great force, from other great bodies, or air ſet free from humour by heat ruſhing out through a pipe (in the inſtrument of Hero of Alexandria, deſcribed in his book *Spiritalia*), then the effluvium would drive everything away, not allure it. But thoſe rarer effluvia take hold of bodies and embrace them as if with arms extended, with the electricks to which they are united; and they are drawn to the ſource, the effluvia increaſing in ſtrength with the proximity. But what is that effluvium from cryſtal, glaſs, and diamond, ſince theſe are bodies of conſiderable hardneſs and firmly concreted? In order that ſuch an effluvium ſhould be produced, there is no need of any marked or perceptible flux of the ſubſtance; nor is it neceſſary that the electrick ſhould be abraded, or worn away, or deformed. Some odoriferous ſubſtances are fragrant for many years, exhaling continually, yet are not quickly conſumed. Cypreſs wood as long as it is found, and it laſts alſo a very long time, is redolent; as many learned men atteſt from experience. Such an electrick only for a moment, when ſtimulated by friction, emits powers far more ſubtile and more fine beyond all odours; yet ſometimes amber, jet, ſulphur, when they are ſomewhat eaſily ſet free into vapour, alſo pour out at the ſame time an odour; and on this account they allure with the very gentleſt rubbing, often even without rubbing; they alſo excite more ſtrongly, and retain hold for a longer time, becauſe they have ſtronger effluvia and laſt longer. But diamond,
* glaſs, rock-cryſtal, and numerous others of the harder and firmly concreted gems firſt grow warm: therefore at firſt they are rubbed longer, and then they alſo attract ſtrongly; nor are they otherwiſe ſet free into vapour. Everything ruſhes towards electricks excepting flame, and flaming bodies, and the thinneſt air. Juſt as they do not draw flame, in like manner they do not affect a ver-
* ſorium, if on any ſide it is very near to a flame, either the flame of a lamp or of any burning matter. It is manifeſt indeed that the effluvia are deſtroyed by flame and igneous heat; and therefore they attract neither flame nor bodies very near a flame. For electrical effluvia

have the virtue of, and are analogous with, extenuated humour; but they will produce their effect, union and continuity, not by the external impulſe of vapours, not by heat and attenuation of heated bodies, but by their humidity itſelf attenuated into its own peculiar effluvia. *
Yet they entice ſmoke ſent out by an extinguiſhed light; and the more that ſmoke is attenuated in ſeeking the upper regions, the leſs ſtrongly is it turned aſide; for things that are too rarefied are not drawn to them; and at length, when it has now almoſt vaniſhed, it does not incline towards them at all, which is eaſily ſeen againſt *
the light. When in fact the ſmoke has paſſed into air, it is not moved, as has been demonſtrated before. For air itſelf, if ſomewhat thin, is not attracted in any way, unleſs on account of ſucceeding that which has vacated its place, as in furnaces and ſuch-like, where the air is fed in by mechanical devices for drawing it in. Therefore an effluvium reſulting from a non-fouling friction, and one which is not changed by heat, but which is its own, cauſes union and cohærency, a prehenſion and a congruence towards its ſource, if only the body to be attracted is not unfitted for motion, either by the ſurroundings of the bodies or by its own weight. To the bodies therefore of the electricks themſelves ſmall bodies are borne. The effluvia extend out their virtue—effluvia which are proper and peculiar to them, and *ſui generis*, differing from common air, being produced from humour, excited by a calorifick motion from attrition and attenuation. And as if they were material rays, they hold and take up chaff, ſtraws, and twigs, until they become extinct or vaniſh away: and then they (the corpuſcles) being looſed again, attracted by the earth itſelf, fall down to the earth. The difference between Magneticks and Electricks is that all magneticks run together with mutual forces; electricks only allure; that which is allured is not changed by an implanted force, but that which has moved up to them voluntarily reſts upon them by the law of matter. *
Bodies are borne towards electricks in a ſtraight line towards the centre of the electrick; a loadſtone draws a loadſtone directly at the poles only, in other parts ob-

liquely and tranſverſely, and in this way alſo they adhere and hang to one another. Electrical motion is a motion of aggregation of matter; magnetical motion is one of diſpoſition and conformation. The globe of the earth is aggregated and cohæres by itſelf electrically. The globe of the earth is directed and turned magnetically; at the ſame time alſo it both cohæres, and in order that it may be ſolid, is in its inmoſt parts cemented together.

A SUMMARY OF GILBERT'S ELECTRICAL WORK.

O distinguish his original discoveries from things already known, Gilbert set in the margin of his book asterisks, large or small, in proportion to the importance of the matter. These have been preserved in the foregoing reprint; and it will be seen that he marked with large asterisks the discovery of the generality of electrifiable bodies, for which he coined the name *electrics*, and the observation that electrified bodies attract not straws and chaff only, but equally attract metals, woods, earths, and even oil and water. The logical outcome of this discovery was the invention of the versorium or *electroscope*. The method of trying everything, instead of accepting statements on authority is characteristic of the man: he must bring all to the touchstone of experiment. The authors who raised Gilbert's wrath by ignorantly copying out all the old tales about amber, jet, and loadstone, instead of investigating the facts, were, as he says at the beginning of the chapter, some theologians, and some physicians. He seems to have taken a special dislike to Albertus Magnus, to Puteanus, to Paracelsus, and to Levinus Lemnius.

Gilbert mentions amber and jet as known to become electrical by friction: but the list was not quite so restricted as would appear from this passage. Five, if not six, other minerals had been mentioned in addition to amber and jet.

(1.) *Lyncurium.* This stone, about which there has been more obscurity and confusion than about any other gem, is supposed by some writers to be the tourmaline, by others a jacinth, and by others a belemnite. The following is the account of Theophrastus, *Theophrastus's History of Stones. With an English Version . . .*, by "Sir" John Hill,

London, 1774, p. 123, ch. xlix.-l. "The *Lapis Lyncurius*, which is likewise used for engraving Seals on, and is of a very solid Texture, as Stones are; it has also an attractive Power, like that of Amber, and is said to attract not only Straws and small pieces of Sticks, but even Copper and Iron, if they are beaten to thin pieces. . . . The *Lapis Lyncurius* is pellucid, and of a fire Colour." See also W. Watson in *Philos. Trans.*, 1759, L. i., p. 394, *Observations concerning the Lyncurium of the ancients.*

(2.) *Ruby.*

(3.) *Garnet.* The authority for both these is Pliny, *Natural History*, book xxxvii., chap. vii. (p. 617 of English edition of 1601).

"Over and besides, I find other sorts of Rubies different from those above-named; . . . which being chaufed in the Sun, or otherwise set in a heat by rubbing with the fingers, will draw unto them chaffe, strawes, shreads, and leaves of paper. The common Grenat also of Carchedon or Carthage, is said to doe as much, although it be inferiour in price to the former."

(4.) *Jasper.* Affaytatus is the authority, in a book called *Physicæ & Astronomicæ cõsiderationes* (Venet., 1549), p. 20.

(5.) *Lychnis.* Pliny and St. Isidore speak of a certain stone *lychnis*, of a scarlet or flame colour, which, when warmed by the sun or between the fingers, attracts straws or leaves of papyrus. Pliny puts this stone amongst carbuncles, but it is much more probably *rubellite*, that is to say, red tourmaline.

(6.) *Diamond.* In spite of a confusion between loadstone and diamond, both of which were called *adamant* by some writers, there seems to be one distinct account of an attractive effect having been observed with a rubbed diamond. This was recorded by Fracastorio, *De sympathiis*, Venice, MDLXXIIII, chap. v., p. 60. An incontestable case of the observation of the electrification of the diamond occurs in Gartias ab Horto, in his *Historia dei Semplici Aromati*, published at Goa in India in 1563.

In Gilbert's list of bodies newly discovered to become electric are several names not now common. The name *iris* was given, there can be little doubt, to clear six-sided prisms of rock-crystal (quartz), which, when held in the sun's beams, cast a crude spectrum of the colours of the rainbow. The following is the account of it given in Pliny, book xxxvii., chap. vii. (p. 623 of the English version of 1601):

". . . there is a stone in name called Iris: digged out of the ground it is in a certaine Island of the red sea, distant from the city Berenice three score miles. For the most part it resembleth Crystall: which is the reason that some hath tearmed it the root of Crystall. But the cause why they call it Iris, is, That if the beames of the Sunne strike upon it directly within house, it doth send from it against the walls that bee neare, the very resemblance both in forme and also in colour of a rainebow; and eftsoones it will chaunge the same in much varietie, to the great admiration of them that behold it. For certain it is knowne, that six angles it hath in manner of the Crystall: but they say that some of them have their sides rugged, and the same unequally angled: which

if they be laid abroad against the Sunne in the open aire, do scatter the beames of the Sunne, which light upon them too and fro: also that others doe yeeld a brightnes from themselves, and thereby illuminat all that is about them. As for the diverse colours which they cast forth, it never happeneth but in a darke or shaddowie place: whereby a man may know, that the varietie of colours is not in the stone Iris, but commeth by the reverberation of the wals. But the best Iris is that which representeth the greatest circles upon the wall, and those which bee likest unto rainebowes indeed."

Iris is also mentioned by Lomatius (*Artes of curious Paintinge*, Haydocke's translation, Lond., 1598, p. 157), who says, ". . . the Sunne, which casting his beames vpon the *stone Iris*, causeth the *raine-bowe* to appeare therein."

The *Vincentina*, or *Bristolla*, or gem of St. Vincent's rock, is nothing else than the so-called "Bristol diamond," a variety of quartz crystallized in small brilliant crystals upon a basis of hæmatite. To the work by Dr. Thomas Venner (Lond., 1650), entitled *Via Recta* or the *Bathes of Bathe*, there is added an appendix, *A Censure concerning the water of Saint Vincents Rocks neer Bristol*, in which, at p. 376, occurs this passage: "This Water of Saint *Vincents* Rock is of a very pure, cleare, crystalline substance, answering to those crystalline Diamonds and transparent stones that are plentifully found in those Clifts." The name *Vincentina* is not known as occurring in any mineralogical book.

Electrical attraction by natural products other than amber, after they have been rubbed, must have been observed by the primitive races of mankind. Indeed Humboldt in his *Cosmos* (Lond., 1860, vol. i., p. 182) records a striking instance:

"I observed with astonishment, on the woody banks of the Orinoco, in the sports of the natives, that the excitement of electricity by friction was known to these savage races, who occupy the very lowest place in the scale of humanity. Children may be seen to rub the dry, flat and shining seeds or husks of a trailing plant (probably a *Negretia*) until they are able to attract threads of cotton and pieces of bamboo cane."

The passage on p. 16 very clearly sets forth the differences to be observed between magnetic and electric effects. Though Gilbert was the first systematically to explore the differences that exist between the magnetic attraction of iron and the electric attraction of all light substances, the point had not passed unheeded, for we find St. Augustine, in the *De Civitate Dei*, liber xxi., cap. 6, raising the question why the loadstone which attracts iron should refuse to move straws. The many analogies between electric and magnetic phenomena had led

many experimenters to speculate on the possibility of some connexion between electricity and magnetism. See, for example, Tiberius Cavallo, *A Treatise on Magnetism*, London, 1787, p. 126. Aepinus wrote a treatise on the subject, entitled *De Similitudine vis electricæ et magneticæ* (Petropolis, 1758). This was, of course, long prior to the discovery, by Oersted, in 1820, of the real connexion between magnetism and the electric current. It is interesting to note on p. 25 a suggestion of material *rays*, as the operation of electric forces seems to foreshadow the notion of electric lines of force.

Gilbert had imbibed the schoolmen's ideas as to the relations of matter and form. He had discovered and noted that in the magnetic attractions there was always a verticity, and that in the electrical attractions the rubbed electrical body had no verticity. To account for these differences he drew the inference that since (as he had satisfied himself) the magnetic actions were due to *form*, that is to say to something immaterial—to an "imponderable" as in the subsequent age it was called—the electrical actions must necessarily be due to *matter*. He therefore put forward his idea that a substance to be an electric must necessarily consist of a concreted humour which is partially resolved into an effluvium by attrition. His discoveries that electric actions would not pass through flame, whilst magnetic actions would, and that electric actions could be screened off by interposing the thinnest layer of fabric such as sarcenet, whilst magnetic actions would penetrate thick slabs of every material except iron only, doubtless confirmed him in attributing the electric forces to the presence of these effluvia. There arose a fashion, which lasted for over a century, for ascribing to "humours," or "fluids," or "effluvia," physical effects which could not otherwise be accounted for.

In spite of his care to test everything by experiment, Gilbert fell into several errors. He denied the existence of electric repulsion, and whilst he strenuously affirmed that the magnetic forces were mutual between the magnet and the iron, each being urged toward the other, he also affirmed that, in the case of the action of the electric on the object which moved toward it, the action was not mutual but was a one-sided force—an impossibility in physics.

Gilbert's experimental discoveries in electricity may be summed up as follows:

1. The generalization of the class of *Electrics*.
2. The observation that damp weather hinders electrification.
3. The generalization that electrified bodies attract everything, including even metals, water, and oil.

4. The invention of the non-magnetic *versorium* or electroscope.
5. The observation that merely warming amber does not electrify it.
6. The recognition of a definite class of *non-electrics*.
7. The observation that certain electrics do not attract if roasted or burnt.
8. That certain electrics when softened by heat lose their power.
9. That the electric effluvia are stopped by the interposition of a sheet of paper or a piece of linen, or by moist air blown from the mouth.
10. That glowing bodies, such as a live coal, brought near excited amber discharge its power.
11. That the heat of the sun, even when concentrated by a burning mirror, confers no vigour on the amber, but dissipates the effluvia.
12. That sulphur and shell-lac when aflame are not electric.
13. That polish is not essential for an electric.
14. That the electric attracts bodies themselves, not the intervening air.
15. That flame is not attracted.
16. That flame destroys the electrical effluvia.
17. That during south winds and in damp weather, glass and crystal, which collect moisture on their surface, are electrically more interfered with than amber, jet and sulphur, which do not so easily take up moisture on their surfaces.
18. That pure oil does not hinder production of electrification or exercise of attraction.
19. That smoke is electrically attracted, unless too rare.
20. That the attraction by an electric is in a straight line toward it.

Gilbert's list of electrics should be compared with those given subsequently by Cabeus (1629), by Sir Thomas Browne (1646), and by Bacon. The last-named copied out Gilbert's list almost without change. Sir Thomas Browne's list is given in the following passage, which is interesting as using for the first time in the English language the noun *Electricities*:

"Many stones also both precious and vulgar, although terse and smooth, have not this power attractive; as Emeralds, Pearle, Jaspis, Corneleans, Agathe, Heliotropes, Marble, Alablaster, Touchstone, Flint and Bezoar. Glasse attracts but weakely though cleere, some slick stones and thick glasses indifferently: Arsenic but weakely, so likewise glasse of Antimony, but Crocus Metallorum not at all. Saltes generally but weakely, as Sal Gemma, Alum, and also Talke; nor very discoverably by any frication: but if gently warmed at the fire, and wiped with a dry cloth, they will better discover their Electricities" (*Pseudodoxia Epidemica*, p. 79).

If, as shown above, the electric powers of diamond and ruby had already been observed, yet Gilbert was the first beyond question to extend the list of *electrics* beyond the class of precious stones, and his discovery that *glass*, *sulphur*, and *sealing-wax* acted, when rubbed, like amber, was of capital importance. So was also his observation that electrical experiments succeed better in dry or frosty weather. Though he did not pursue the discovery into mechanical contrivances, he left the

means of that extension to his followers. To Otto von Guericke we owe the application of *sulphur* to make the first electrical machine out of a revolving globe; to Sir Isaac Newton and to Hauksbee the suggestion of *glass* as affording a more mechanical construction. And both materials were discovered by Gilbert to be electrics.

"Such," said Priestley in 1767, "were the discoveries of our countryman Gilbert, who may justly be called the father of modern electricity, though it be true that he left his child in its very infancy." To Priestley's quaint remark we may add that as electricity is no longer in its infancy, we who claim Gilbert as our countryman are all the more proud to acknowledge his just claims to its paternity.

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